LASER-PRINTED LABELS IN WET COLLECTIONS: WILL THEY HOLD UP?

KRISTA ZALA,[1] N. DEAN PENTCHEFF,[2] AND REGINA WETZER[1]

[1]*Natural History Museum of Los Angeles County, Research and Collections, 900 Exposition Blvd., Los Angeles, California 90007, USA*
[2]*Loyola Marymount University, 1 LMU Drive, Los Angeles, California 90045, USA*

Abstract.—Biological specimens are identified by a printed label detailing their collection and curation information. Deterioration of specimen labels can render specimens scientifically valueless. Given that this problem is a threat to wet-preserved collections, it is critically important to know which label preparation techniques will withstand decades of immersion in common preservatives. Traditional print methods that have lasted for centuries, such as writing in pencil or India ink on cotton rag paper, are time-consuming and not amenable to producing multiple copies of labels. Laser-printing technology greatly increases label production rates, but its durability on assorted label papers or stored in common preservatives has not been quantitatively tested.

This 14-yr study examines the durability of laser print on five museum-quality papers. We evaluate the effects of post-printing heat and acrylic-coating treatments on print durability in the presence of two preservative types, formalin and ethanol. All treatments remained legible at the end of the trial. The treatments that maintained the greatest print legibility were acrylic-coated (vs. uncoated) labels and labels immersed in ethanol (vs. formalin solution). Paper type and microwave treatment did not affect print durability.

INTRODUCTION

Cost-effective methods for creating durable specimen labels are of paramount concern for collection managers. The practice of writing locality information and specimen identifications by hand on cotton rag paper, using either graphite pencil or India ink, has resulted in labels that remain intact for decades or centuries. Unfortunately, handwriting styles can be hard to read due to poor penmanship or old-fashioned styles that are difficult to decipher. Generating labels by typewriting began to replace handwriting following the widespread availability and use of typewriters in the 20th century. Typewriter print standardizes the lettering and a non-bleeding durable ink minimizes blurring and fading. Still, this method has its shortcomings; for example, producing small (6- to 9-point) type is difficult and aligning type on small labels can be a slow and cumbersome process.

Handwriting with pencil and typing both require pressure to make a mark on the paper, so if the mark fades, tracing the depression may allow data recovery. Liquid inks have the advantage of being absorbed into paper and thus are more resistant to abrasion. However, both methods are time-consuming and each copy in label production is subject to human error. As the roles of collection management staff expand and the numbers of acquisitions increase, any effort to shorten or improve the printing of labels is welcomed.

Electronic technologies offer several efficient alternatives to traditional labeling methods, but the long-term durability of labels created from printing equipment developed in the last few decades remains unknown. Technologies of note include daisy-wheel, dot-matrix, and laser printers. The daisy-wheel is a character printer, where a disk with raised letters along its edge rotates, and a hammer strikes the disk against an ink ribbon, transferring ink to paper and making an imprint on the page. Print speeds range from 0.5 to 3 pages per minute (ppm). A desired change in font or typeface requires changing the wheel itself, an unwieldy procedure for specimen labeling. Although largely replaced by other technologies, daisy-wheel printers and replacement parts are still available. In dot-matrix printers, pins are struck against an ink ribbon, also leaving ink and an imprint on the paper. Print speed is three ppm, but the aesthetic quality of print is lower than most other methods (Sims 1990), and its low number of dots per inch (dpi) can make text appear faint.

Advantages of laser printing include the chemical stability of the toner and the notably faster print speed. An eight ppm minimum speed for high quality print means that label creation is not the rate-determining step in curating specimen lots. Despite these advantages, laser-printed labels have been controversial since their introduction in the 1980s because of concerns about the durability of the print in fluid preservatives (Wheeler et al. 2001, Nelson 1990, Sims 1989, 1990). Most concerns stem from its different print technology (Apple Computers 1985). A laser light selectively discharges a positively-charged drum in the form of the characters or image to be printed. The discharged portions of the drum attract the positively-charged dry toner powder. Dry toner for monochrome laser printers consists of a black pigment combined with small particles composed of plastic resins, soot, and partly magnetized metal oxides. The toner sticks to the negatively-charged paper surface and the powder is discharged so it detaches from the drum. The sheet of paper passes through fusion rollers that bond the loose toner to the paper using heat and pressure, yielding crisp and clear type. Unlike ink and impact printing methods, laser printing deposits a raised, melted powder but the toner neither penetrates the paper nor leaves a depression, which raises issues of label durability, specifically, durability of fused toner and toner-paper bond strength (Wheeler et al. 2001), and effects of preservatives and specimens on the print.

Several ichthyology collection managers have observed rapid print loss of laser-printed labels in wet-preserved collections (A. Suzumoto pers. comm., J. Seigel pers. comm., A. Bentley pers. comm.). Snyder (1999) cites high lipid content of specimens as a probable primary agent in loosening the toner-paper bond, with the preservative possibly accelerating the deterioration process.

Heat and pressure are factors in toner adhesion (National Archives of Australia 2000). Thus, strategies for enhancing the bonds between toner and paper have generally relied on various heat applications. Printing methods include feeding a page through the printer twice (keeping it blank the first time), or printing labels at the end of a lengthy print run when the fusion rollers are presumed to be hotter than usual. Common post-printing methods of heat application include using a flat-iron press, oven, or microwave oven. One post-printing chemical treatment to strengthen or protect the toner-paper bond is clear acrylic spray. This method has been used by one of us (RW) at the San Diego Natural History Museum and by collection managers at Cornell University, NY (D. Nelson pers. comm.) and the Academy of Natural Sciences, PA (W. Saul pers. comm.).

Previous attempts to test the durability of these methods have generated mixed results. An unpublished study comparing heat treatments and papers found that baking and dry-mount pressing labels (e.g., as used for mounting photographic prints) preserved print far better than heating them in microwave ovens (K. Kishinami pers. comm.). K. Reed (pers. comm.) compared print quality of labels printed by different methods. Labels were immersed in commonly used museum preservatives (including 70% ethanol, 95% ethanol, and 10% formalin solution) and water for 13 mo. Laser-printed labels remained in excellent condition after immersion in these preservatives, with no evidence of deteriorating sharpness of letters.

Sims (1989) found that mainframe laser printers that use increased heat and pressure printed durable labels whereas print on labels from a desktop laser printer flaked off the paper. Labels printed with a desktop laser printer and placed in jars of ethanol with fish specimens failed an abrasion test (Nelson 1990). In this qualitative assessment, Nelson stated that after immersing labels for three weeks in standard museum preservatives, ''a light rubbing with a finger easily removed the print from the paper surface.'' Wheeler et al. (2001) reported that laser-printed labels at the Royal Ontario Museum have remained immersed in ethanol ''for over ten years with no apparent loss of label quality,'' whereas entire letters were lost from labels shipped with loan specimens nine months after immersion. Without more information about specimen storage conditions, preservative solutions, and types of biological specimens involved, it is impossible to explain these divergent results.

No peer-reviewed literature exists addressing the issue of durability of laser-printed labels in wet-preserved collections. This is surprising given the interest expressed in various professional communications (Nelson 1990, Sims 1989, 1990, Wheeler et al. 2001). We investigate the long-term durability of labels generated using a desktop laser printer. Four factors were tested for their effect on print durability: preservative (70% ethanol or 10% formalin), paper type, post-printing heat treatment, and post-printing chemical treatment.

Materials and Methods

We tested five paper types, all 100% cotton rag: Resistall Ledger 36 lbs (Byron Weston, Dalton, MA), Permalife Ledger 32 lbs (Latmer and Mayer, Pittsburgh, PA), Suture Label 102 lbs, lot #4-2-1388 (Domtar, Montreal, Quebec), Wet Strength Laundry Tag 70 lbs lot #4-3-2707 (Domtar), and Supra 100 45 lbs (Paper Technologies, Laguna Nigel, CA). Requests to collection managers of natural history museums for readily available 100% cotton rag papers suitable for wet collections established three common paper types. At the time of the experiment's design, Resistall Ledger was used at the Canadian Museum of Nature (P. Frank pers. comm.) and the Natural History Museum of Los Angeles County (NHMLAC) (RW); Permalife was used at the Bishop Museum (A. Suzumoto pers. comm.) and the San Diego Natural History Museum (RW); and Wet Strength Laundry tag was used at the United States National Museum and the Academy of Natural Sciences (W. Saul pers. comm.) and at the Museum of Zoology, University of Michigan (Nelson 1990). Requests to paper manufacturing companies for same yielded two more paper types: Domtar's Suture Label and Paper Technologies' Supra 100.

Labels were printed in March 1989 using the Apple LaserWriter Plus equipped with a Canon LBP-CX laser-xerographic engine (a monochrome 300 dpi laser printer that prints at 8 ppm at 200°C). Labels were printed eight to a sheet using a new factory-filled toner cartridge from Canon. After printing, sheets were sliced into 5.0 cm by 12.5 cm labels. Two labels of each paper type were treated in one of four ways: (a) heated in a household microwave for 3 min on its highest setting, (b) sprayed with a clear acrylic spray (manufactured by Krylon®) and air-dried overnight, (c) both heated and sprayed with acrylic, or (d) untreated after printing. Each label was placed in its own 118-ml glass specimen jar containing either 10% unbuffered formalin solution or 70% ethanol solution in distilled water, such that the printed side of the label was flush against the inner wall of the jar. Formalin is actually a 37.5% formaldehyde solution, thus a 10% formalin solution is 3.75% formaldehyde. Each jar was sealed with a polypropylene lid containing a Teflon® liner to minimize evaporation and changes in preservative concentration. Jars were stored together in a single closed cardboard box to shield them from light. Samples were not held in a temperature-controlled environment, a condition shared by many museum collections (Fink et al. 1979). During the 14 yr of this experiment, jars were moved among four institutions, involving 2 cross-country moves. There was no noticeable evaporation or leakage from the jars during this time.

The experiment was terminated in March 2003. Labels were inspected using a microscope at 60× magnification and graded. Damage was so slight that there were no significant differences between treatments (results not reported here). To increase discernable differences between treatments, labels were subjected to a quantifiable accelerated aging process. The Technical Association of the Pulp and Paper Industry (TAPPI) T-830 Digital Ink Rub Tester, available at California Polytechnic Institute, San Luis Obispo, was used to abrade the labels. The Digital Ink Rub Tester has a stage on which the test paper is mounted. A 0.9 kg (2 lb) rubber-lined weight fits over the stage. The weight was fitted with glass microscope slides to simulate rubbing of the test label against the glass wall of a specimen jar. In operation, the testing machine moves the weighted glass slides over the fixed specimen for 50 back-and-forth cycles.

Printed labels were dried and then cut into six pieces with dimensions of 2.5 cm by 4.1 cm. Two samples were taken from each label, each of which had 10 rows with the letters ‘‘ar’’ printed on them. Each label sample was mounted on a 5 cm by 21.25 cm piece of Resistall paper using Lohmann Adhesive’s Duplofol 0.10 mm double-sided adhesive tape to prevent the sample from slipping during the test. All samples were re-wetted with 70% ethanol, subjected to 50 rub cycles, then dried and returned to the NHMLAC for analysis. Experimental conditions prevented re-wetting with formalin.

To prevent evaluator bias, a random number was assigned to each sample. One of us (KZ) evaluated all label damage using a binocular dissecting scope at 60× magnification and two fiber optic lights. Samples were ranked based on a scoring system defining levels of toner flaking where 1 = chipped, 2 = cracked, and 8 = section missing (Fig. 1). Weights were assigned to each of the categories to try to represent the effect on readability. We also performed an analysis assigning each damage category a value of 1 and it yielded the same statistical results (analysis not shown). When letters showed multiple areas of flaking, we counted the number of areas subjected to the three categories of toner damage, multiplied each by respective rank, and summed the values in the three categories.

A total of eighty samples (5 paper treatments × 2 preservative treatments × 2 heat treatments × 2 chemical treatments × 2 samples per label) was evaluated

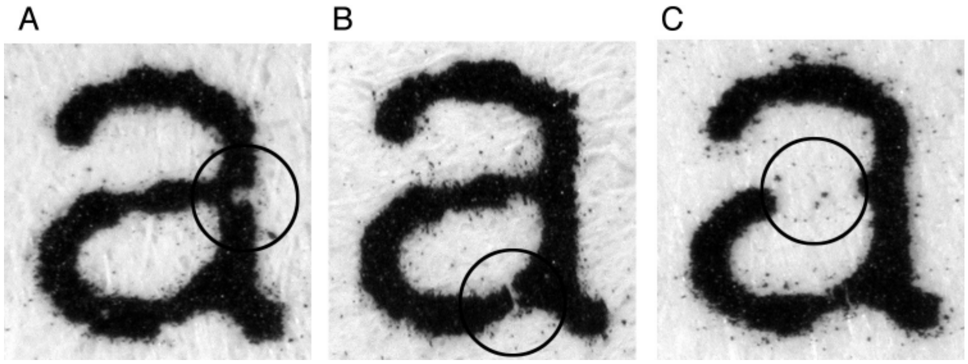

Figure 1. Examples of three categories of toner flaking where defined A = chipped; B = cracked; and C = section missing.

and ranked using the summed damage scores in a single ordinal scheme. The value of tied ranks was replaced with the mean rank of each tie group (Zar 1998). Four comparisons of the ranked samples were performed: (1) acrylic coated vs. uncoated; (2) microwave heated vs. not heated; (3) ethanol vs. formalin preservative; and (4) paper types. The first three treatment pairs were compared using the normal approximation to the Mann-Whitney *U*-test, adjusted for continuity. This test is appropriate for non-parametric comparisons where there are more than 20 samples in a group (Zar 1998). A Kruskal-Wallace test was used to compare the five paper treatments (Zar 1998). A significance level of alpha = 0.05 was used. Critical values of alpha = 0.0125 were used for the tests based on a Bonferroni correction of alpha to account for the multiple comparisons (Miller 1981). A Spearman rank correlation was used to determine the strength of the association between the replicates within the ranked data (Zar 1998).

Results

All letters were fully readable after the 14-yr immersion and remained in readable condition after the TAPPI T-830 accelerated aging procedure. In some instances the paper was abraded or frayed, mainly at the edges, with damage attributed to edge effects. No bleeding or fading of print was observed. Most damage to print was either ''chipping'' or ''cracking,'' with few letters sustaining ''section missing'' damage.

Statistical analysis of the four sets of comparisons of ranked samples showed a significant effect of two of the four treatments (Fig. 2). Statistical results were the same when performed on equally weighted damage categories (not shown). Labels coated with acrylic (Krylon®) spray were significantly less damaged than uncoated labels ($P < 0.001$). Labels immersed in 70% ethanol solution were significantly less damaged than labels immersed in 10% formalin solution ($P < 0.001$). There was no significant difference ($P > 0.05$) between microwaved and non-microwaved samples or between paper types.

A Spearman rank correlation between the forty pairs of replicate samples yielded a correlation $r^2 = 0.60$ ($p < 0.001$), indicating a strong similarity in rank between replicates. This supports the consistency of the effects of treatment and analysis on the samples.

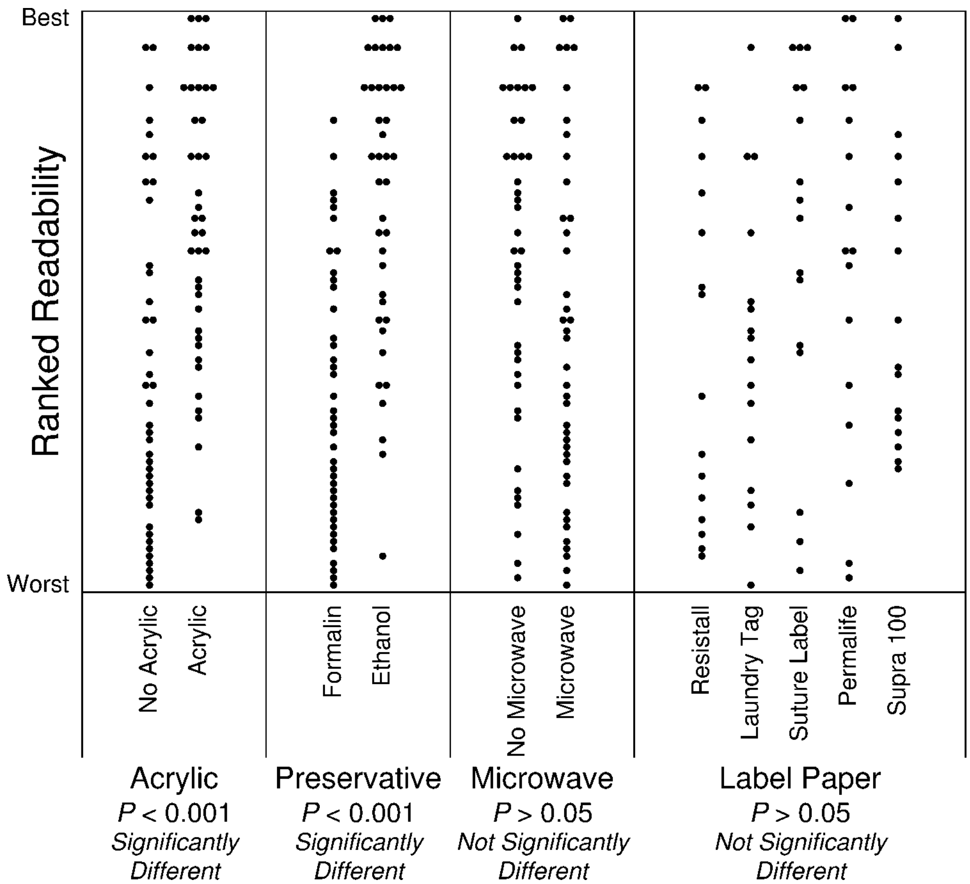

Figure 2. Comparisons of ranked readability for treatment groups of samples. Within each treatment, parallel dots indicate tied ranks. Significance levels for comparisons within treatment groups are given beneath each group (see Materials and Methods for details).

Discussion

Our results indicate that application of acrylic coating to labels after laser printing increases the durability of the label. One explanation for this increase in durability is that the spray coating may shield the toner-paper bond from detrimental effects of the preservative. Observed under magnification, acrylic-coated print appears fluid and shiny, which contrasts with the more dull and particulate appearance of uncoated toner. The toner's liquid appearance suggests that the acrylic may ''melt'' it, thereby further bonding the toner to itself.

C. Hawks (pers. comm.) cited two possible drawbacks to the use of acrylic coating: paper stiffening and delamination (the separation of layers) of the coating from the paper. Hawks postulated that (1) stiff paper threatens label integrity, particularly if labels need to be flexed or folded to fit the container, and (2) delamination could render a label illegible if the toner bonds more strongly to the spray than to the paper and the coating delaminates, because the print would peel with the coating from the paper. Our experiments did not directly address either issue, but we saw neither of these problems. We do not know how much acrylic leaches from the paper in alcohol or formalin solutions, nor do we know how acrylic affects specimens. No connection between specimen deterioration and acrylic-coating has been reported in the literature, but the threat of damage to specimens from acrylic-coated labels remains a deterrent for some collection managers.

Our data indicate that preservatives have differing effects on label durability. Differences may stem from the chemical properties of preservatives (e.g., pH levels). Formalin solution is acidic. This situation may be ameliorated or exacerbated by the use of agents to buffer formalin. The acidity of even a 10% solution may weaken the toner-paper bond, while ethanol's negligible dissociation may have little or no effect. There is a possibility that the subsequent exposure of formalin-preserved labels to ethanol during the Ink Rub Test may have compromised label integrity more than labels immersed in ethanol only. It is worth noting, however, that successive exposure of labels from formalin to alcohol frequently occurs as collections are transferred from formalin to alcohol solutions.

Microwave treatment, a print-preserving method, had no significant effect in this study. This treatment's failure to affect samples is most likely attributable to the heating mechanism employed. Microwave ovens work by emitting radio waves at approximately 2.5 GHz. This frequency heats food components including water, fats, and sugars, but has little effect on plastics, ceramics, and glass. The toner used in this experiment (and by most laser printers) is a plastic polymer, which likely remains unaffected by the microwave's range of radio waves. Because of this, we feel we did not adequately test heat application as a means of increasing label durability. Although we do not recommend microwave treatment as it had no significant effect on print durability, we believe that direct heat application merits further investigation.

Desktop laser printers on the market today have not changed their optimal printing specifications. They still print at roughly 200°C, and can handle up to 36 lb bond paper. Heavier bond papers likely achieve lower surface temperatures than their thinner, lighter counterparts in their rapid pass between the fusion rollers. The manufacturer's suggested optimal paper weight for the LaserWriter Plus is 16–20 lb bond. Its full range is 8–34 lb bond paper (Apple Computers 1985). Several of the papers tested were considerably heavier than 34 lb bond. However, despite testing a range of paper weight, no paper type held the toner-paper bond significantly better than any other, which suggests that paper weight (i.e., thickness) may not have affected the bonding processes. None of the five papers tested is rejected for laser-printed labels.

The results of this study provide no reason to suggest that laser printed labels should not be used with biological specimen lots stored in 70% ethanol or 10% formalin. Labels in alcohol may be more durable, but both solutions are acceptable. Until biological and chemical agents affecting the toner-paper bond are identified, laser-printed labels placed in jars with specimens cannot be unconditionally recommended. Similarly, until the effects of acrylic spray on specimens are tested, acrylic-coating cannot be recommended as a treatment for any labels that share fluid preservative with specimens.

This study establishes the ability of laser-printed labels on a variety of cotton rag papers to withstand immersion in commonly used preservative solutions for 14 yr without discernable deterioration. Microwave treatment is ineffective in increasing durability. Coating with Krylon® acrylic spray does increase durability, but may be undesirable because of unknown interactions between acrylic and biological specimens. As 14 yr is a relatively short time in the life of a preserved scientific specimen, we also recommend having a redundant labeling method using different media, e.g., a small label with the catalog number written in India ink, to ensure against data loss over time.

We are aware that none of the similar studies we have cited is published in a peer-reviewed journal, which clearly indicates a need for more scientifically formulated, replicable experiments with quantitative results. Future research should address the interactions of biological specimens with laser printed labels and the effect of acrylic spray on specimens.

Acknowledgments

We are grateful to our colleagues Kathy Omura and Darolyn Striley for participating in the road trips between Los Angeles and San Luis Obispo and for their good humor and untiring help in preparing samples for the TAPPI-standard Digital Ink Rub Tester. We thank Walter Horelick of the Graphic Communication Department at California Polytechnic Institute, San Luis Obispo, for enabling our access to the facilities and for his hospitality. We gratefully acknowledge Peter Frank, Cathy Hawks, Carla Kishinami, Doug Nelson, Karen Reed, William Saul, Jeff Seigel, John Simmons, Arnold Suzumoto, and countless other collections care staff with whom we have had invaluable discussions about specimen label preparation over the years. Thanks also go to Simon Grove and Andy Bentley for their helpful comments on label issues. This manuscript benefited from comments by Andy Bentley, Paisley Cato, John Simmons, and Arnold Suzumoto. Finally, this project acknowledges the support of National Science Foundation Collections Grant, DBI-0138674.

Literature Cited

Apple Computers. 1985. LaserWriter/LaserWriter Plus Owner's Guide. In Article 50128. Available at http://docs.info.apple.com/article.html?artnum=50128 (30 November 2004).

Fink, W.L., K.E. Hartel, W.G. Saul, E.M. Koon, and E.O. Wiley. 1979. A report on current supplies and practices used in curation of ichthyological collections. American Society of Ichthyologists and Herpetologists *ad hoc* Subcommittee Report, 63 pp.

Miller, R.G. 1981. *Simultaneous Statistical Inference,* 2nd ed. Springer Verlag. 299 pp.

National Archives of Australia. 2000. Photocopies and laser prints. Available at http://www.naa.gov.au/recordkeeping/rkpubs/advices/advice37.html (30 November 2004).

Nelson, D.W. 1990. Further comments on laser printer generated jar labels. American Society of Ichthyologists and Herpetologists Curation Newsletter 10:3.

Sims, L. 1989. How permanent are they? Insect Collection News 2(2):26.

Sims, L. 1990. An analysis of the suitability of various laser and impact printer generated labels for wet label storage. American Society of Ichthyologists and Herpetologists Curation Newsletter 10: 2–3.

Snyder, A.M. 1999. Mechanical and manual production of labels for collections stored in fluids: A few examples of papers, ink and production protocols. American Society of Ichthyologists and Herpetologists Curation Newsletter 12. Available at http://www.asih.org/coms/ihcc/news/cnl12.html (30 November 2004).

Wheeler, T.A., J.T. Huber, and D.C. Currie. 2001. *Label data standards for terrestrial arthropods.* Biological Survey of Canada (Terrestrial Arthropods). Ottawa, Canada. 22 pp.

Zar, J.H. 1998. *Biostatistical Analysis,* 4th ed. Prentice Hall. 718 pp.

Associate Editor: Cindy Ramotnik